Designation: ~~D5887/D5887M – 22~~ D5887/D5887M – 22a

Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter[1]

This standard is issued under the fixed designation D5887/D5887M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers an index test that covers laboratory measurement of flux through saturated geosynthetic clay liner (GCL) specimens using a flexible wall permeameter.

1.2 This test method is applicable to GCL products having geotextile backing(s). It is not applicable to GCL products with geomembrane backing(s), geofilm backing(s), or polymer coating backing(s).

1.3 This test method provides a measurement of flux under a prescribed set of conditions that can be used for manufacturing quality control. The test method can also be used to check conformance. The flux value determined using this test method is not considered to be representative of the in-service flux of GCLs.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D374/D374M Test Methods for Thickness of Solid Electrical Insulation
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D4439 Terminology for Geosynthetics
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.04 on Geosynthetic Clay Liners.

Current edition approved ~~May 1, 2022~~Oct. 1, 2022. Published ~~May 2022~~October 2022. Originally approved in 1995. Last previous edition approved in ~~2020~~2022 as ~~D5887/D5887M – 20.~~D5887/D5887M – 22. DOI: ~~10.1520/D5887_D5887M-22.~~10.1520/D5887_D5887M-22A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *flux, n*—the rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a GCL specimen.

3.1.2 *geosynthetic clay liner (GCL), n*—a factory-manufactured geosynthetic hydraulic barrier consisting of clay supported by geotextiles or geomembranes, or both, that are held together by needling, stitching, or chemical adhesives.

3.1.3 *index test, n*—a test procedure that may contain a bias, but that may be used to establish an order for a set of specimens with respect to the property of interest.

3.1.4 For definitions of other terms used in this test method, see Terminologies D653 and D4439.

4. Summary of Test Method

4.1 This test method involves permeation of a 100-mm [4-in.] diameter GCL test specimen. The specimen is set up in a flexible wall permeameter and subjected to a total stress of 550 kPa [80 psi] and a back pressure of 515 kPa [75 psi] for a period of 48 h. Flow is initiated using deionized water by raising the pressure on the influent side of the test specimen to 530 kPa [77 psi]. The flux is determined when inflow and outflow are approximately equal (within ±25 %).

5. Significance and Use

5.1 This test method yields the flux of water through a saturated GCL specimen that is consolidated, hydrated, and permeated under a prescribed set of conditions.

5.2 This test method can be performed to determine if the flux of a GCL specimen exceeds the maximum value stated by the manufacturer.

5.3 This test method can be used to determine the variation in flux within a sample of GCL by testing a number of different specimens.

5.4 This test method does not provide a flux value to be used directly in design calculations.

NOTE 1—Flux for in-service conditions depends on a number of factors, including confining pressure, type of hydration fluid, degree of hydration, degree of saturation, type of permeating fluid, and hydraulic gradient. Correlation between flux values obtained with this test method and flux through GCLs subjected to in-service conditions has not been fully investigated.

5.5 This test method does not provide a value of hydraulic conductivity. Although hydraulic conductivity can be determined in a manner similar to the method described in this test method, the thickness of the specimen is needed to calculate hydraulic conductivity. This test method does not include procedures for measuring the thickness of the GCL nor of the clay component within the GCL. Refer to Appendix X2 for calculation of hydraulic conductivity.

5.6 The apparatus used in this test method is commonly used to determine the hydraulic conductivity of soil specimens. However, flux values measured in this test are typically much lower than those commonly measured for most natural soils. It is essential that the leakage rate of the apparatus used in this test be less than 10 % of the flux.

6. Apparatus

6.1 *Hydraulic System,* constant head (Test Method A), falling head (Test Methods B and C), or constant rate of flow (Test Method D) systems may be utilized provided they meet the criteria outlined as follows:

6.1.1 *Constant Head*—The system shall be capable of maintaining constant hydraulic pressures to within ±5 % and shall include means to measure the hydraulic pressures to within the prescribed tolerance. In addition, the head loss across the test specimen

must be held constant to within ±5 % and shall be measured with the same accuracy or better. Pressures shall be measured by a pressure gauge, electronic pressure transducer, or any other device of suitable accuracy.

6.1.2 *Falling Head*—The system shall allow for measurement of the applied head loss to within ±5 % at any time. In addition, the ratio of initial head loss divided by final head loss over an interval of time shall be measured such that this computed ratio is accurate to within ±5 %. The head loss shall be measured with a pressure gauge, electronic pressure transducer, engineer's scale, graduated pipette, or any other device of suitable accuracy. Falling head tests may be performed with either a constant tailwater elevation (Test Method B) or a rising tailwater elevation (Test Method C).

6.1.3 *Constant Rate of Flow*—The system shall be capable of maintaining a constant rate of flow through the specimen to within ±5 %. Flow measurement shall be by calibrated syringe, graduated pipette, or other device of suitable accuracy. The head loss across the specimens shall be measured to an accuracy of ±5 % using an electronic pressure transducer or other device of suitable accuracy. More information on testing with a constant rate of flow is given in the literature.[3]

6.1.4 *System De-Airing*—The hydraulic system shall be designed to facilitate rapid and complete removal of free air bubbles from flow lines.

6.1.5 *Back Pressure System*—The hydraulic system shall have the capability to apply back pressure to the specimen to facilitate saturation. The system shall be capable of maintaining the applied back pressure throughout the duration of hydraulic conductivity measurements. The back pressure system shall be capable of applying, controlling, and measuring the back pressure within ±5 % of the applied pressure. The back pressure may be provided by a compressed gas supply, a deadweight acting on a piston, or any other method capable of applying and controlling the back pressure to the tolerance prescribed in this paragraph.

NOTE 2—Application of gas pressure directly to a fluid will dissolve gas in the fluid. A variety of techniques are available to minimize dissolution of gas in the back pressure fluid, including separation of gas and liquid phases with a bladder and frequent replacement of the liquid with de-aired water.

6.2 *Flow Measurement System*—Both inflow and outflow volumes shall be measured unless the lack of leakage, continuity of flow, and cessation of consolidation or swelling can be verified by other means. Flow volumes shall be measured by a graduated accumulator, graduated pipette, vertical standpipe in conjunction with an electronic pressure transducer, or other volume-measuring device of suitable accuracy.

6.2.1 *Flow Accuracy*—Required accuracy for the quantity of flow measured over an interval of time is ±5 %.

6.2.2 *De-Airing and Compliance of the System*—The flow-measurement system shall contain a minimum of dead space and be capable of complete and rapid de-airing. Compliance of the system in response to changes in pressure shall be minimized by using a stiff flow measurement system. Rigid tubing, such as metallic or rigid thermoplastic tubing, shall be used.

6.2.3 *Head Losses*—Head losses in the tubes, valves, porous end pieces, and filter paper may lead to error. To guard against such errors, the permeameter shall be assembled with no specimen inside and then the hydraulic system filled. If a constant or falling head test is to be used, the hydraulic pressures or heads that will be used in testing a specimen shall be applied, and the rate of flow measured with an accuracy of ±5 %. This rate of flow shall be at least ten times greater than the rate of flow that is measured when a specimen is placed inside the permeameter and the same hydraulic pressures or heads are applied. If a constant rate of flow test is to be used, the rate of flow to be used in testing a specimen shall be supplied to the permeameter and the head loss measured. The head loss without a specimen shall be less than 0.1 times the head loss when a specimen is present.

6.3 *Permeameter Cell Pressure System*—The system for pressurizing the permeameter cell shall be capable of applying and controlling the cell pressure to within ±5 % of the applied pressure. However, the effective stress on the test specimen shall be maintained to the desired value with an accuracy of ±5 %. The device for pressurizing the cell may consist of a reservoir connected to the permeameter cell and partially filled with de-aired water, with the upper part of the reservoir connected to a compressed gas supply or other source of pressure (see Note 3). The gas pressure shall be controlled by a pressure regulator and measured by a pressure gauge, electronic pressure transducer, or any other device capable of measuring to the prescribed tolerance. A hydraulic system pressurized by deadweight acting on a piston or any other pressure device capable of applying and controlling the permeameter cell pressure to the tolerance prescribed in this paragraph may be used.

NOTE 3—De-aired water is commonly used for the cell fluid to minimize potential for diffusion of air through the membrane into the specimen. Other

[3] Olson, H. W., Morin, R. H., and Nichols, R. W., "Flow Pump Applications in Triaxial Testing," *Symposium on Advanced Triaxial Testing of Soil and Rock, ASTM STP 977*, ASTM International, 1988, pp. 68–81.

fluids, such as oils, which have low gas solubilities, are also acceptable provided they do not react with components of the permeameter and the flexible membrane. Also, use of a long (approximately 5 to 7 m) tube connecting the pressurized cell liquid to cell helps to delay the appearance of air in the cell fluid and to reduce the flux of dissolved air into the cell.

6.4 *Permeameter Cell*—An apparatus shall be provided in which the specimen and porous end pieces, enclosed by a flexible membrane sealed to the cap and base, are subjected to controlled fluid pressures. A schematic diagram of a typical cell is shown in Fig. 1.

6.4.1 The permeameter cell may allow for observation of changes in height of the specimen, either by observation through the cell wall using a cathetometer or other instrument, or by monitoring of either a loading piston or an extensometer extending through the top plate of the cell bearing on the top cap and attached to a dial indicator or other measuring device. The piston or extensometer should pass through a bushing and seal incorporated into the top plate and shall be loaded with sufficient force to compensate for the cell pressure acting over the cross-sectional area of the piston where it passes through the seal. If deformations are measured, the deformation indicator shall be a dial indicator or cathetometer graduated to 0.3 mm [0.01 in.] or better and having an adequate travel range. Any other measuring device meeting these requirements is acceptable.

6.4.2 To facilitate gas removal, and thus saturation of the hydraulic system, four drainage lines leading to the specimen, two each to the base and top cap, are recommended. The drainage lines shall be controlled by no-volume-change valves, such as ball valves, and shall be designed to minimize dead space in the lines.

6.5 *Top Cap and Base*—An impermeable, rigid top cap and base shall be used to support the specimen and provide for transmission of permanent liquid to and from the specimen. The diameter or width of the top cap and base shall be equal to the diameter or width of the specimen ±5 %. The base shall prevent leakage, lateral motion, or tilting, and the top cap shall be designed to receive the piston or extensometer, if used, such that the piston-to-top-cap contact area is concentric with the cap. The surface of the base and top cap that contacts the membrane to form a seal shall be smooth and free of scratches.

6.6 *Flexible Membranes*—The flexible membrane used to encase the specimen shall provide reliable protection against leakage. The membrane shall be carefully inspected prior to use and if any flaws or pinholes are evident, the membrane shall be discarded. To minimize restraint of the specimen, the diameter or width of the unstretched membrane shall be between 90 and 95 % of that of the specimen. The membrane shall be sealed to the specimen base and cap with rubber O-rings for which the unstressed, inside diameter or width is less than 90 % of the diameter or width of the base and cap, or by any other method that will produce an adequate seal.

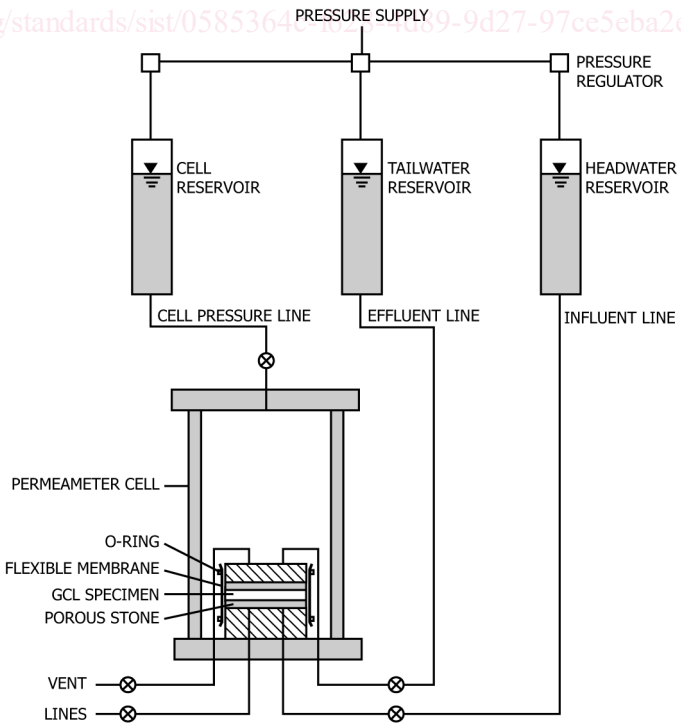

FIG. 1 Permeameter Cell and Test Setup

NOTE 4—Membranes may be tested for flaws by placing them around a form sealed at both ends with rubber O-rings, subjecting them to a small air pressure on the inside, and then dipping them into water. If air bubbles come up from any point on the membrane, or if any visible flaws are observed, the membrane shall be discarded.

6.7 *Porous End Pieces*—The porous end pieces shall be of silicon carbide, aluminum oxide, or other material that is not attacked by the specimen or permanent liquid. The end pieces shall have plane and smooth surfaces and be free of cracks, chips, and nonuniformities. They shall be checked regularly to ensure that they are not clogged.

6.7.1 The porous end pieces shall have a diameter no greater than 100 mm [3.95 in.] and no less than 98 mm [3.85 in.], and the thickness shall be sufficient to prevent breaking.

6.7.2 The hydraulic conductivity of the porous end pieces shall be substantially greater than that of the specimen to be tested such that there is no significant impedance of flow. Including the porous end pieces in the procedures set forth in 6.2.3 will ensure that no significant impedance occurs.

6.8 *Filter Paper*—To prevent intrusion of material into the pores of the porous end pieces, one or more sheets of filter paper shall be placed between the top and bottom porous end pieces and the specimen (see Note 5). The hydraulic conductivity of the filter paper shall be substantially greater than that of the specimen to be tested such that there is no significant impedance of flow. Including the filter paper in the procedures set forth in 6.2.3 will ensure that no significant impedance occurs.

NOTE 5—The type of filter paper recommended is Whatman No. 1 (or equivalent), that has particle retention capability greater than 11 μm.

6.9 *Devices for Measuring the Dimensions of the Specimen*—Devices used to measure the dimensions of the specimen shall be capable of measuring to the nearest 0.3 mm [0.01 in.] or better and shall be constructed such that their use will not disturb the specimen.

6.10 *Balances*—The balance shall be suitable for determining the mass of the specimen and shall be selected as discussed in Guide D4753. The mass of specimens shall be determined to the nearest 0.01 g.

6.11 *Equipment for Mounting the Specimen*—Equipment for mounting the specimen in the permeameter cell shall include a membrane stretcher or cylinder and ring for expanding and placing O-rings on the base and top cap to seal the membrane.

6.12 *Vacuum Pump*—To assist with de-airing of permeameter system and saturation of specimens.

6.13 *Temperature Maintaining Device*—The temperature of the permeameter, test specimen, and permeant reservoir shall be maintained at 21 ± 2 °C. Normally, this is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in a water bath, insulated chamber, or other device that maintains a temperature within the specified tolerance. The temperature shall be periodically measured and recorded at a minimum at the beginning of the permeation phase and at the end of the permeation phase of the test.

6.14 *Water Content Containers*—The containers shall be in accordance with Test Methods D2216.

6.15 *Drying Oven*—The oven shall be in accordance with Specification E145.

7. Reagents

7.1 *Permeant Water:*

7.1.1 The permeant water is the liquid used to permeate the test specimen and is also the liquid used in back pressuring the specimen. The flux through a GCL specimen can be substantially influenced by the permeating fluid. Deionized water shall be used in this test method.

7.1.2 The permeant water shall be de-aired as well as deionized. The water is usually de-aired by boiling, by spraying a fine mist

of water into an evacuated vessel attached to vacuum source, or by forceful agitation of water in a container attached to a vacuum source. De-aired water shall not be exposed to air for prolonged periods.

8. Test Specimen Preparation

8.1 Inspect the bulk GCL sample to be tested and record any disturbance, irregularity, or damages. Choose a representative section of the GCL sample to obtain the specimen for testing.

8.2 Place a template with a known area (for example, 30.5 by 30.5 cm [12 by 12 in.]) on the selected section.

8.3 Utilizing a sharp utility knife or other suitable instruments, cut the bulk GCL sample to the exact size of the template. Carefully remove, with little or no loss of bentonite, and weigh the cut GCL sample (see Note 6).

NOTE 6—The weight of the GCL sample and the area of the template could be used to provide an estimate of the mass per unit area of the GCL sample.

8.4 If necessary, utilizing a squirt bottle with a long nozzle and filled with deionized water, wet the edges of the GCL sample to prevent bentonite loss during further handling and specimen preparation.

8.5 Carefully place the GCL sample on a flat, smooth surface.

8.6 Place a 100 ± 1-mm [4 ± 0.04-in.] diameter disc at the center of the GCL sample. With a thin marker, trace around the disc directly on the GCL backing.

8.7 Remove the disc. Using a sharp utility knife or other suitable instruments (see Note 7), cut through the traced line and into the upper GCL backing.

NOTE 7—Depending upon the type of geotextile backing, heated fine-pointed soldering iron or carpet knives have been successfully used for this purpose.

8.8 Utilizing a squirt bottle with a long nozzle, apply deionized water on the cut line. Allow the bentonite to hydrate for 2 to 5 min.

8.9 Using a sharp pair of scissors or other suitable instruments, cut through the bentonite and the lower geotextile backing on the cut line. Add deionized water to the exposed bentonite, if required, to prevent any loss of bentonite.

8.10 Examine the exposed edge of the specimen to verify that geotextile fibers from the upper and lower geotextile backings are not interconnected. To ensure that fibers from the upper and lower geotextile backings are not connected, the edge of the geotextile backings may be slightly trimmed using a pair of sharp scissors.

NOTE 8—Once trimmed, a bentonite paste can be applied to the edges of the GCL to limit side wall leakage. Bentonite of the same nature used to seal around the specimen edges should be taken from the GCL sample or production run bentonite, with the bentonite source noted on the test report. Bentonite paste should be made using deionized ~~distilled~~ water. The bentonite paste should only be applied with minimal pressure along the outside perimeter, not on the top surface of the specimen. The bentonite should not be used to restore bentonite lost from specimen edges due to poor handling.

8.11 The diameter of the specimen shall not be less than the diameter of the disc and no greater than 102 mm [4.02 in.].

9. Procedure

9.1 *Specimen Setup:*

9.1.1 Cut two filter paper sheets 100 ± 2 mm [4 ± 0.08 in.] in diameter. Soak the two porous end pieces and filter paper sheet, if used, in a container of permeant (that is, deionized, de-aired water).

9.1.2 Place the membrane on the membrane expander. Apply a thin coat of silicon high-vacuum grease to the sides of the end caps. Place a porous end piece on the permeameter base cap, followed by a piece of filter paper, followed by the test specimen. Place

a piece of filter paper on top of the specimen, followed by a porous end piece and the top cap. Place the membrane around the specimen and, using the membrane expander or other suitable O-ring expander, place two O-rings on each end cap to seal the membrane.

9.1.3 Attach flow tubing to the top cap, if not already attached, assemble the permeameter cell, and fill it with water or other cell fluid. Attach the cell pressure reservoir to the permeameter cell line and the hydraulic system to the influent and effluent lines. Fill the cell pressure reservoir with water or other suitable liquid, and the hydraulic system with deionized, de-aired permeant water.

9.2 *Consolidation and Back Pressure Saturation:*

9.2.1 Increase the cell pressure to 35 kPa [5 psi] and the back pressure to 7 to 14 kPa [2 to 3 psi] on both ends of the specimen. Carefully flush permeant water through the drainage lines until all visible air bubbles have been removed.

NOTE 9—The following de-airing procedure has been found to work on falling head/rising tailwater apparatus. Flush permeant water through the influent and effluent lines by opening and closing the bleed valves. The entire permeability cell should be flipped upside down. Rattle then rest the cell repeatedly for 3 min. Verify if air is still trapped under the specimen visually by observing the translucent line on the bottom of the cell. If air bubbles exist, burp the bubbles out of the line by disconnecting the quick connect and discharging a little fluid by engaging the male connector on a hard surface. Flip the cell back upright.

9.2.2 Increase the cell pressure and back pressure simultaneously in increments of 70 kPa [10 psi] in 10-min minimum intervals until a final cell pressure of 550 kPa [80 psi] and a back pressure of 515 kPa [75 psi] are obtained.

9.2.3 Maintain the cell pressure of 550 kPa [80 psi] and back pressure of 515 kPa [75 psi] for a minimum period of 48 h to allow consolidation/swell, saturation, and hydration to occur.

9.3 *Permeation:*

9.3.1 Initiate permeation by raising the pressure at the base of the specimen (producing upward flow through the test specimen) so that the pressure difference across the specimen is 15 ± 0.5 kPa [2 ± 0.1 psi]. This will result in an influent pressure of 530 kPa [77 psi]. The average effective confining pressure is then 27.5 kPa [4 psi].

9.3.2 Determine the head loss across the specimen with an accuracy of ±10 %. In addition, for falling head tests, the pressure difference shall not fall below 10 kPa [1.5 psi]. The pressure difference between two consecutive readings shall be accurate to ±20 %.

9.3.3 Determine the rate of inflow and the rate of outflow with an accuracy of ±10 %.

9.3.4 Determine the room temperature or the temperature of the test liquid (see 6.13).

9.4 *Termination Criteria:*

9.4.1 The following criteria shall be met for a test to be considered complete:

9.4.2 At least three values of flow rate shall be determined over a minimum time period of ~~8 h.~~24 h.

9.4.3 The ratio of rate of inflow to rate of outflow shall be between 0.75 and 1.25 for the last three consecutive flow measurements.

9.4.4 There shall be no significant upward or downward trend in flow rate for the last three consecutive readings.

9.4.5 None of the last three flow rate values shall be less than 0.75 times the average flow rate value nor greater than 1.25 times the average value.

9.4.6 The reported q_i value is computed by averaging the last three consecutive computed values.

NOTE 10—In some cases, the termination criteria may be satisfied prior to reaching the actual equilibrium flux value. It is recommend that the testing laboratory continue the test for a longer duration (potentially two to three weeks) if the flux value is greater than the expected or specified value, or both.